NASA TECHNICAL TRANSLATION NASA TT F-14,377

THE UPPER LIMIT OF BRIGHTNESS FLUCTUATIONS OF BACKGROUND RADIATION IN THE 1-5 mm REGION

V. S. Soglasnova

Translation of: "Verkhniy Predel Fluktuatsiy Yarkosti Fonovogo Izlucheniya v Oblasti ot 1 do 5 mm," Moscow, Institute of Space Research, Academy of Sciences USSR, Report Pr-87, 1971, 7 pages.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 JULY 1972

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ABSTRACT: This is a report of a series of observations measuring small scale background radiation fluctuations in the 1-5 mm wavelength interval. The observations were made at the Crimean Astrophysical Observatory on an RT-22 telescope with the help of a liquid helium cooled receiver of indium antimonide.

Relic radiation is the dominant background radiation in the region of the centimeter and millimeter wavelengths. Measurements on the wavelengths from 75 centimeters to 3.3 millimeters have shown that this radiation is Planck radiation at a temperature of 2.65°K. Measurements on shorter wavelengths cannot be conducted from the Earth due to strong atmospheric absorption; therefore, rockets and balloons are used for these observations. Such measurements, carried out in the past few years [1-3], have shown that there is a surplus of background radiation above the expected level of Planck radiation, although the most recent measurements of the background in the range from 0.8 to 6 millimeters [4] give an equivalent blackbody temperature of $3.1 \pm {}^{0.5}_{2.0}$ °K. /3*

Investigation of the fluctuation of background radiation in the centimeter wavelength [5] has shown a high degree of isotropy ($\Delta T/T < 4 \cdot 10^{-4}$). The presence of this surplus of background radiation can lead to an increase in the level of fluctuation of the background by $\lambda < 3$ millimeters; therefore,

*Numbers in the margin indicate pagination in the foreign text.

we conducted a series of observations with the goal of measuring small-scale fluctuations in the 1-5 millimeter wavelength interval.

The observations were conducted in May and June of 1970 on the RT-22 telescope of the Crimean Astrophysical Observatory with the help of a liquid helium-cooled receiver of indium antimonide. The sensitivity of the receiver /4 is practically constant in the 1-5 millimeter range and decreases smoothly toward the shortwave end. The extraterrestrial radiation received by the radiometer in the shortwave region was limited by passage through the atmosphere. Radiation originating in the atmosphere on wavelengths shorter than 1 millimeter was removed by a low-frequency filter. The receiver is described in detail in [6]. Diagram modulation was used to decrease the effect of atmospheric radiation fluctuation on the sensitivity of the radiometer. The width of the directivity diagram at half power is 2.0; the distance between the scanning beam and the comparison beam is 4.1 with a time constant of 10 seconds.

The observations were carried out at night with a clear sky. The quality of the recordings depended on the condition of the atmosphere; during processing, 30% of all the recordings were selected with a minimal level of fluctuation caused by the atmosphere. Multiple scans were made of the sections of the sky with direct descent from $\alpha_{1950} = 15^h53^m00^s$ to $\alpha_{1950} = 15^h54^m20^s$ with inclination of $\delta_{1950} = 19°20'$, including the galaxy Markaryan 291.

The registered fluctuations $I_j(i)$ represent deviation of the observed signal from the mean level of the j-th scan at the i-th point. The average of the N recordings at the i-th point equals:

$$I_N(i) = \frac{1}{N}\sum_{j=1}^{N} I_j(i). \tag{1}$$

The scatter of the recording, received after averaging the scans, equals:

$$\sigma^2(N) = \frac{1}{n}\sum_{i=1}^{n} I^2_N(i), \tag{2}$$

where n is the number of readings in a scan. On the other hand, the scatter of the averaged process at the output of the radiometer may be represented in the form: /5

$$\sigma^2(N) = \frac{\sigma_0^2}{N} + 2\sigma_\varphi^2, \qquad (3)$$

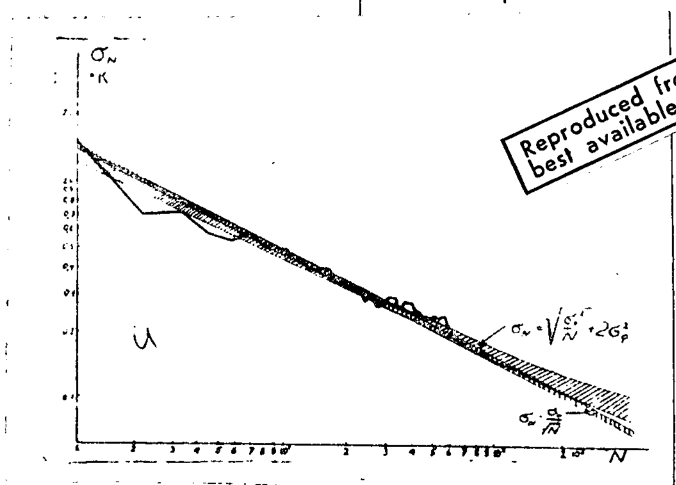
where N is the number of averaged recordings; $\sigma^2 \simeq \sigma^2$ (1) is the mean scatter of a single recording ($\sigma_0^2 \gg \sigma_b^2$), σ_b^2 is the scatter of background fluctuation. Doubling the scatter σ_b^2 in (3) occurs in the case of angülar scales $\theta \ll 4'$ due to the diagram modulation, since the fluctuations are not correlated.

The magnitude 2 σ_b^2, the asymptote of the function (3), and σ_0^2 were found by the method of least squares from the solution of an equation system of the form (3). For 57 of the best recordings, with respect to weather conditions, σ_b = (2.5 ± 7.4)10^{-2} was taken as the temperature intensity.

The dependence of $\sigma(N)$ on the number of average scans is shown in Figure 1, which also shows the most satisfactory function according to the observational data (3) with σ_b = 0. Although the sum of the squares of the deviations of $\sigma(N)$ from this line is 1.28 times greater than from the curve (3), the observational data are insufficient to draw a conclusion concerning the presence or absence of background fluctuation. The value of σ taken directly from measurements is exactly 0.172°K when N = 57, which gives an upper estimate of σ_b < 0.122°K. Calibration was accomplished using Jupiter, for which a brightness temperature of 145°K was obtained. During referencing for determining the magnitude of absorption and the effective reception wave, the variation of the spectral transparency of the atmosphere with altitude was calculated using the Sun as a control with the Fabry-Perot interferometer [7]. The effective wavelength for the Rayleigh-Jeans region (Jupiter) was 1.36 millimeters, and for 3-Planck radiation it was 2.45 millimeters. /6

The obtained upper boundary of background fluctuation allows evaluation of the number of discrete unresolved sources which may produce such a level of fluctuation. The magnitude of mean square fluctuation σ_b < 0.122°K conforms to a flux of 1.4 · 10^{-25} w/m Hz for a discrete point source. The total number of such sources must be greater than ~$4 \cdot 10^7$.

The author expresses his thanks to V. I. Slysh, G. B. Sholomitskiy and V. F. Zabolotniy for useful discussions and remarks.



Mean Square Fluctuation Versus Number of Averaged Scans.

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Translated for the National Aeronautics and Space Administration under contract No. NASw-2037 by Techtran Corporation, P. O. Box 729, Glen Burnie, Maryland, 21061, translator: Samuel Blalock.